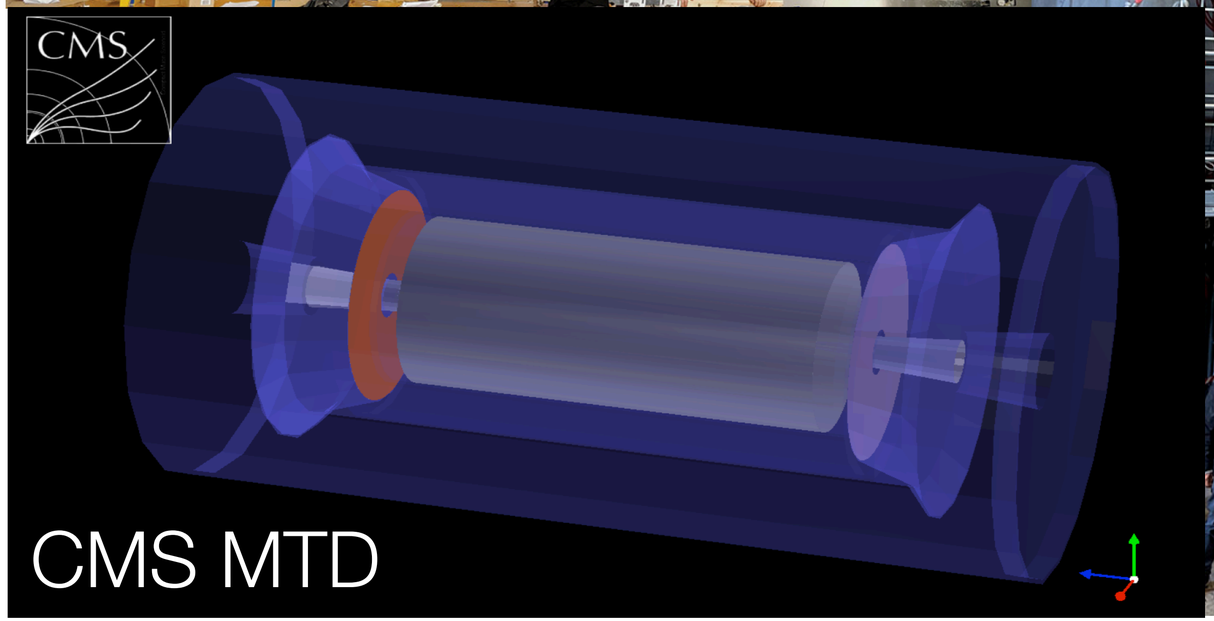
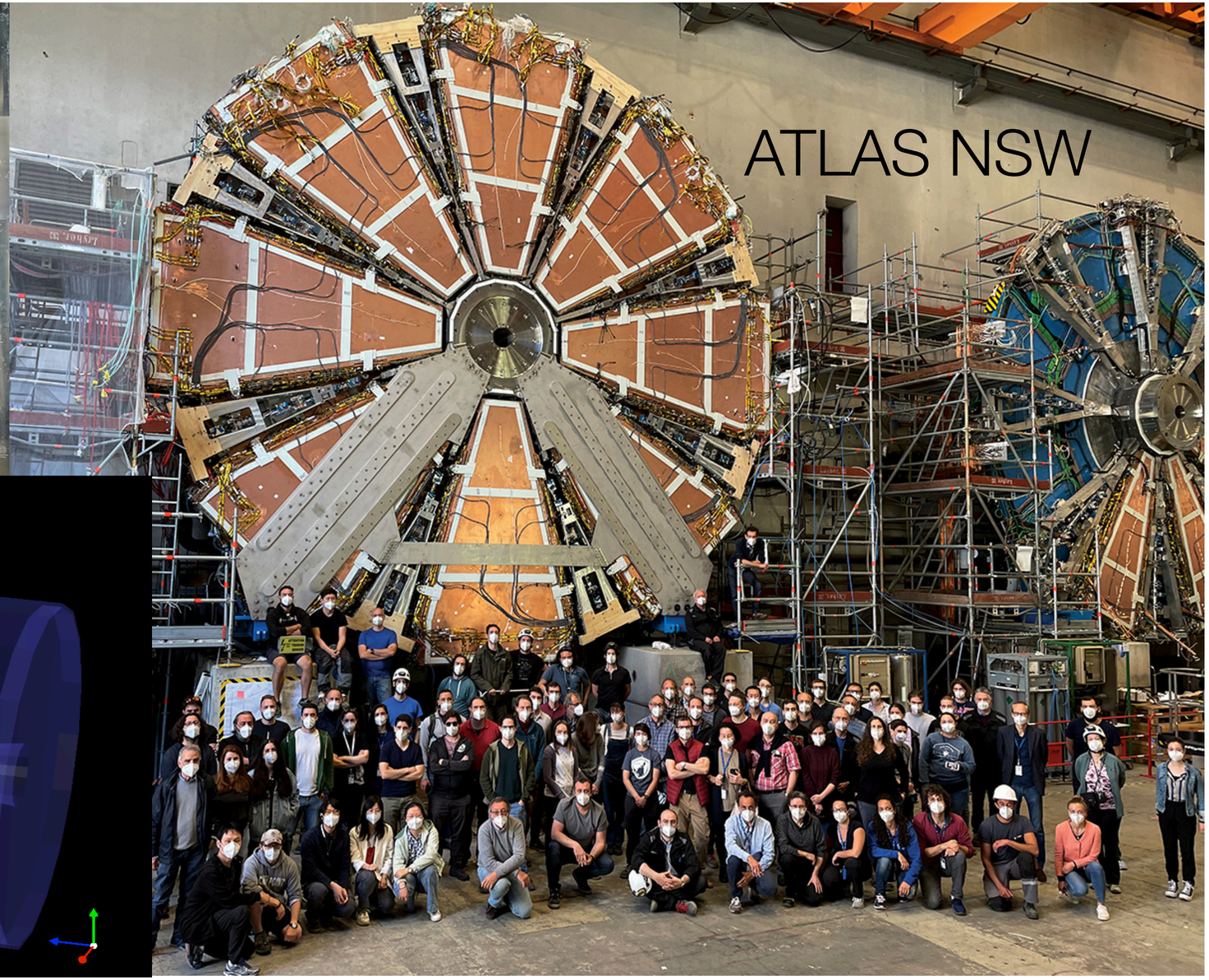
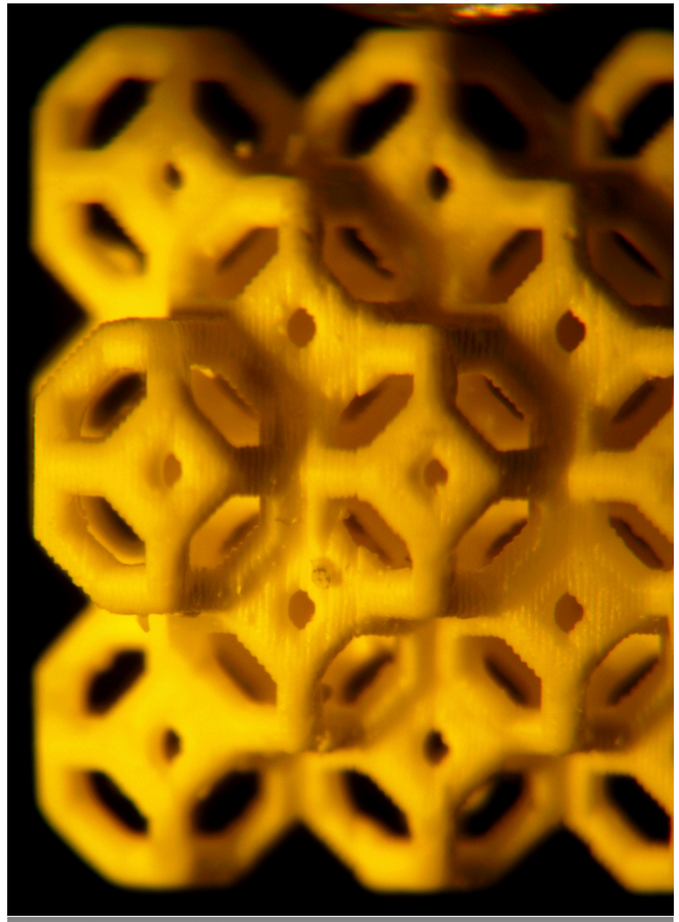
Overview on particle detectors trends

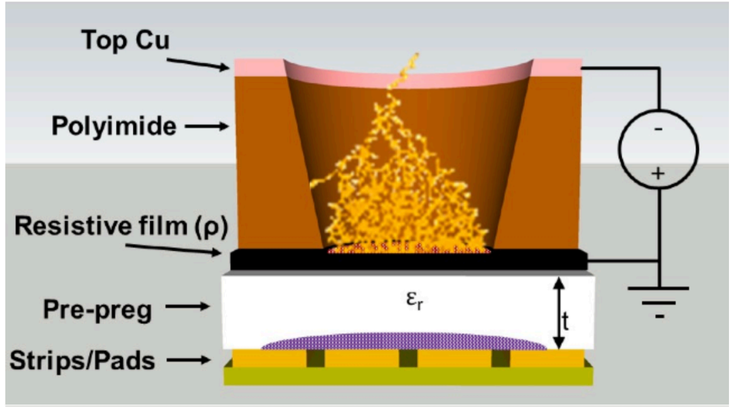
General Trends: Large size for large experiments

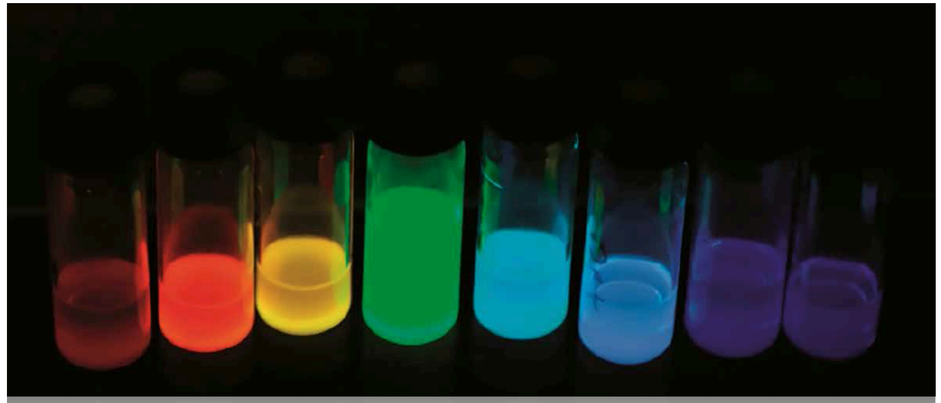


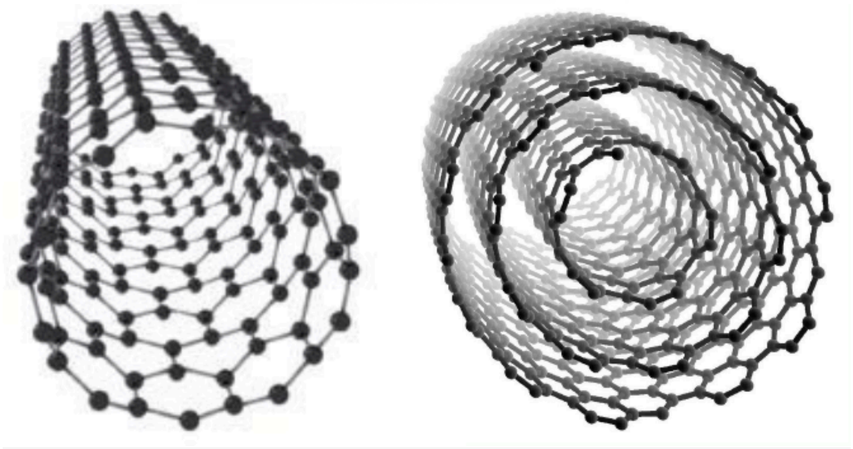


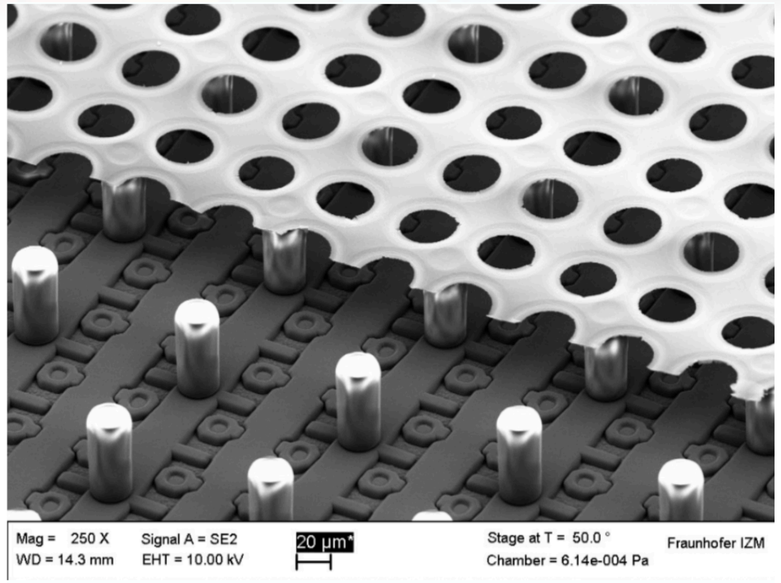
General Trends: miniaturising for novel performance





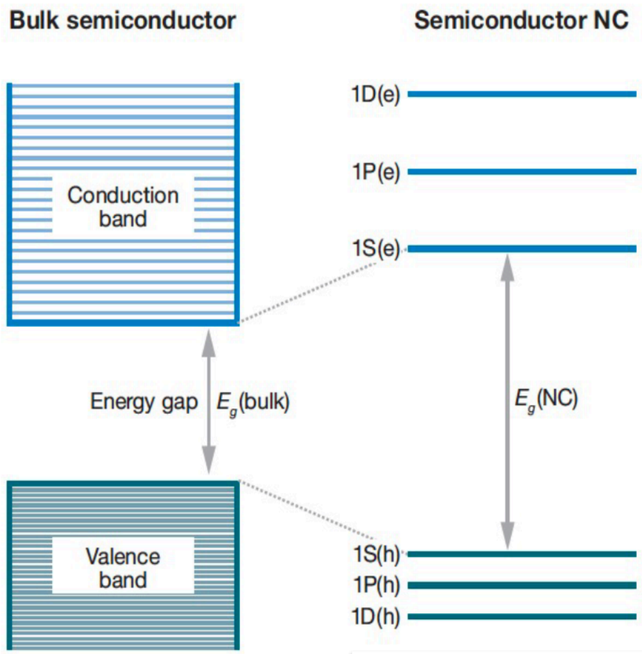


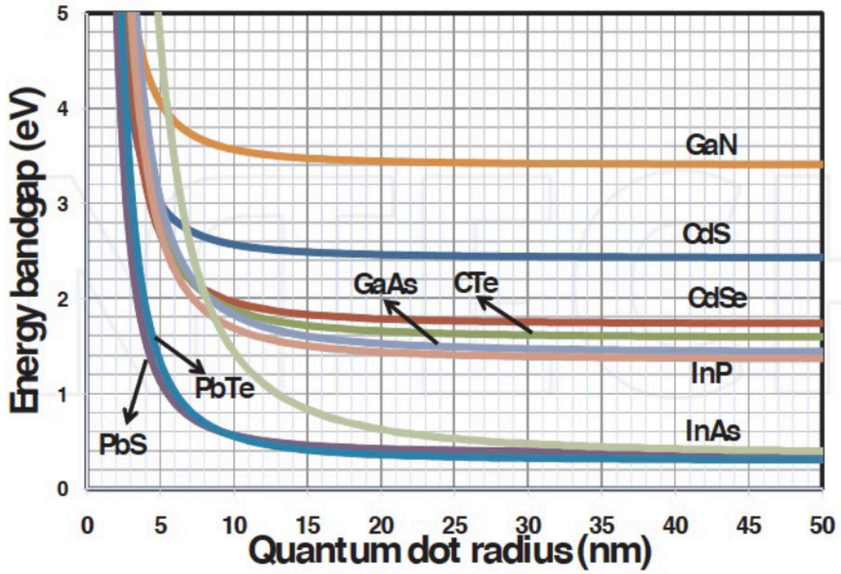


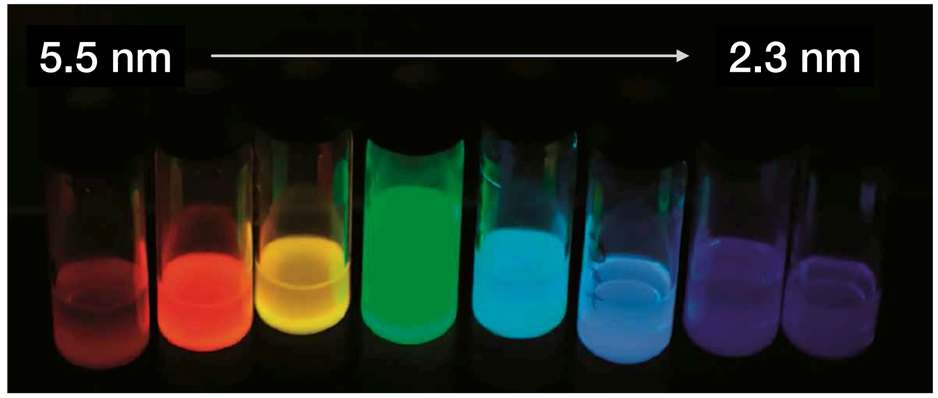


Scintillating Materials: Quantum Dots

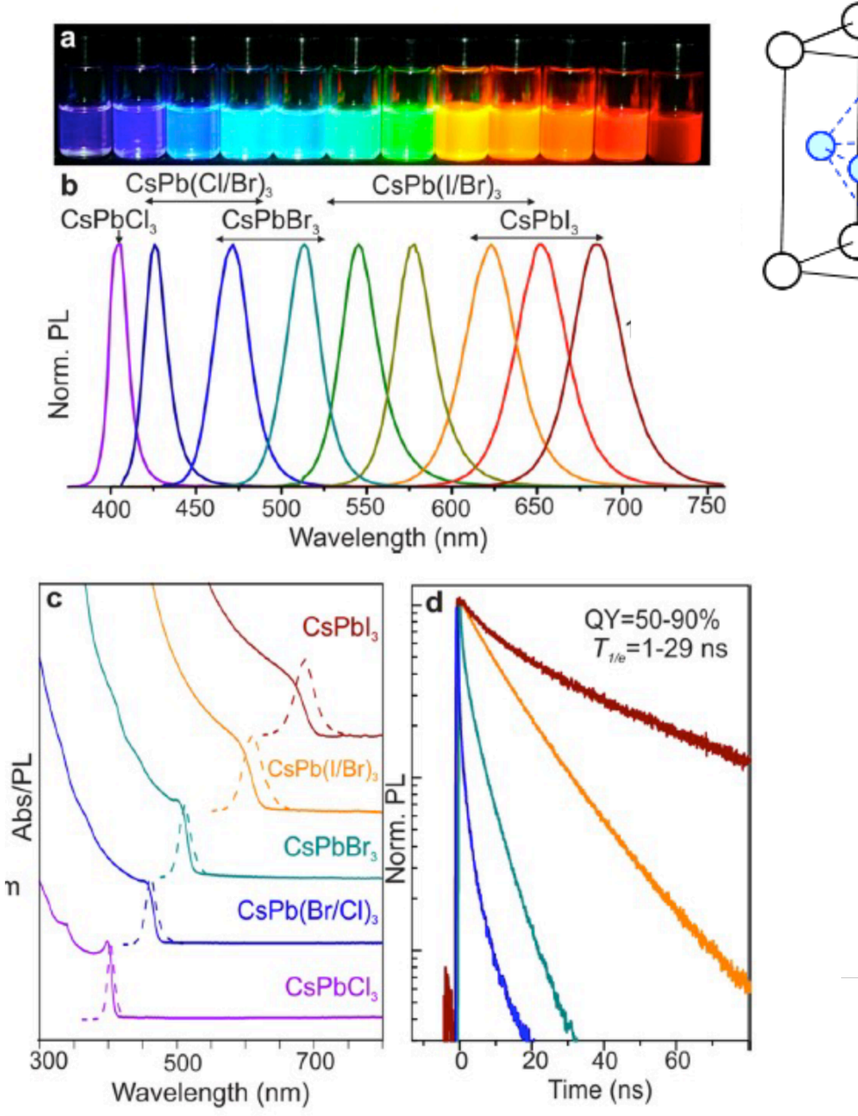
Energy band gap (E_g) varies with quantum dot size

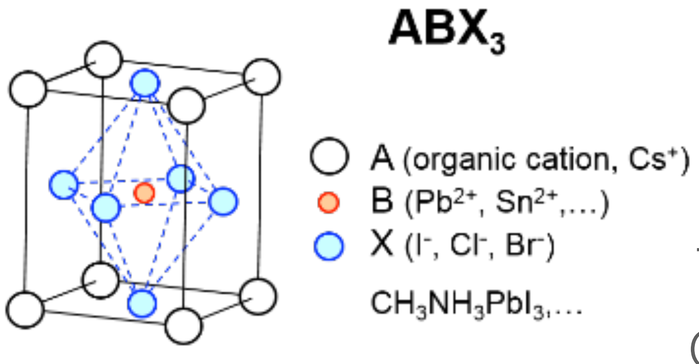






Scintillating Materials: Perov



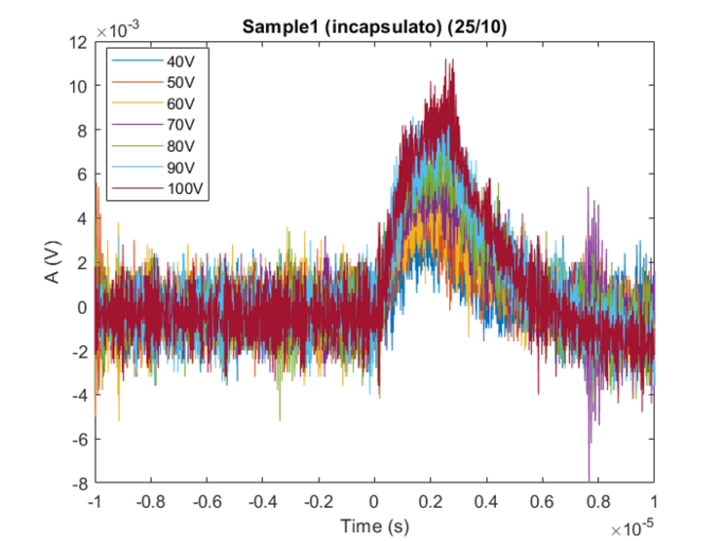


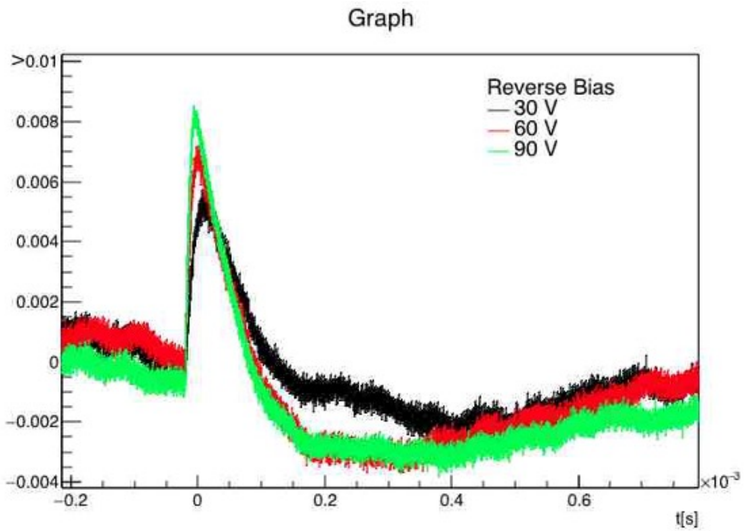
Crystals with **tunable** opto-electronics performance“ that can be used in **tiles**, **films**, **liquids**

They can be used as **scintillating** materials

Or in the **solar cells**…

Or, they can be **polarised** to be used as **photo-diodes**

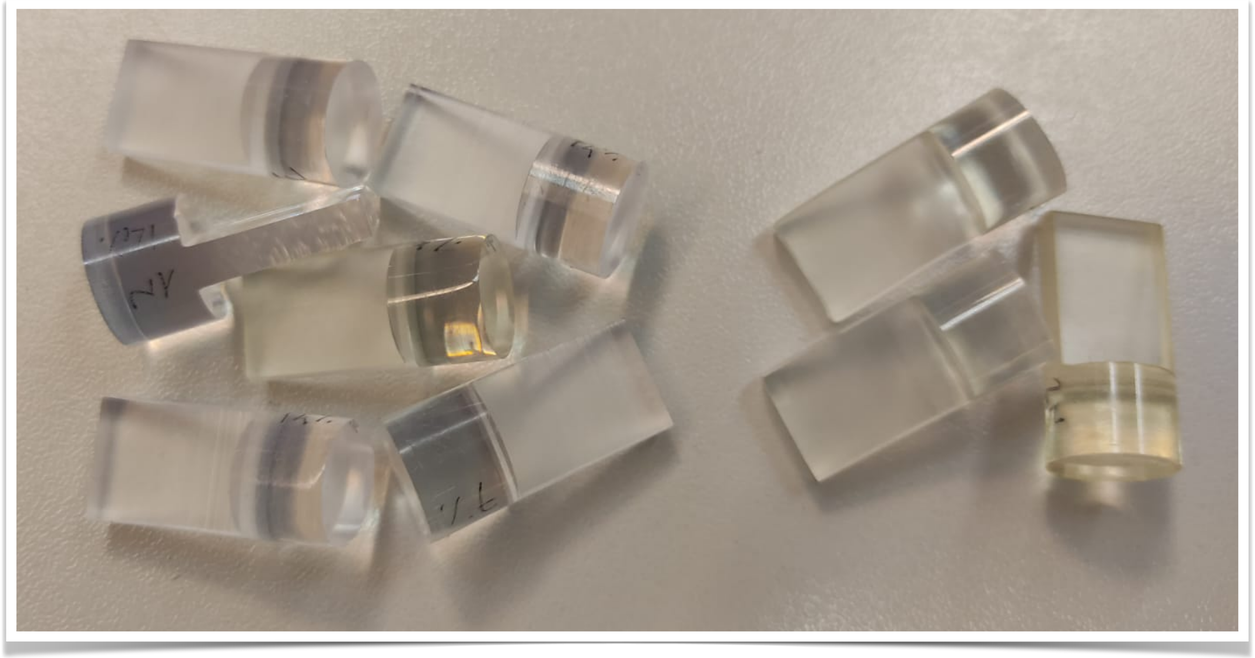


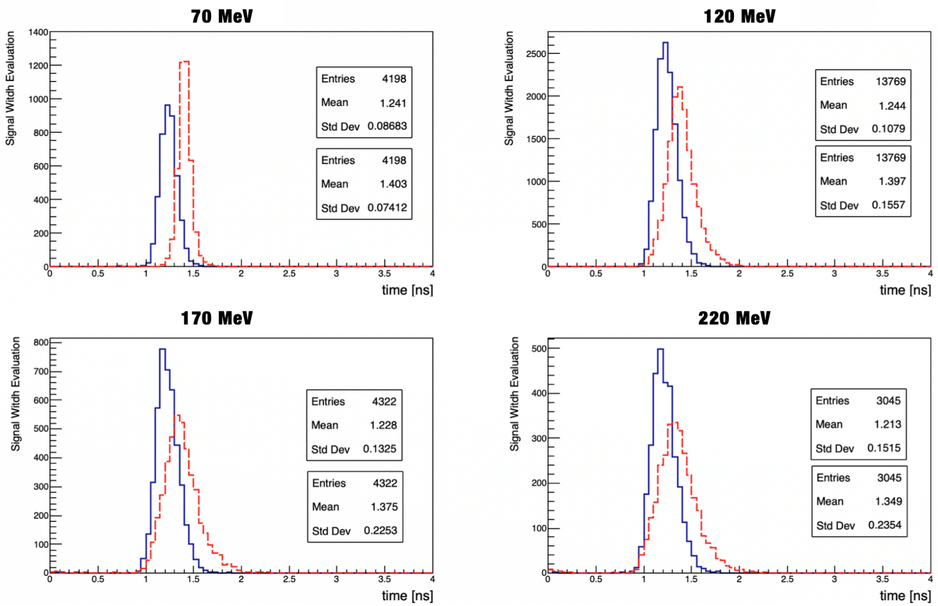


PEROV team (Chiara & Silvio) is studying the possibility of obtaining an internal electric gain

Scintillating Materials: TOPS project

The SBAI-group, in collaboration with colleagues from **Chemistry**, are developing and testing of **new fluorophores** for the production of **fast** and easy to manipulate new **plastic scintillators**



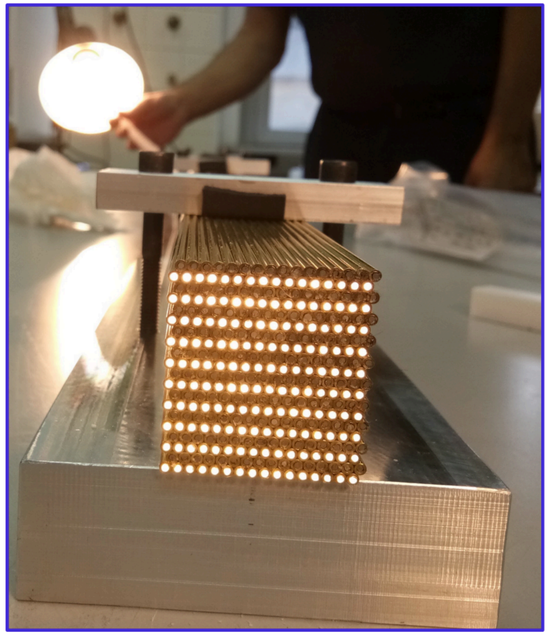


Excellent time resolution

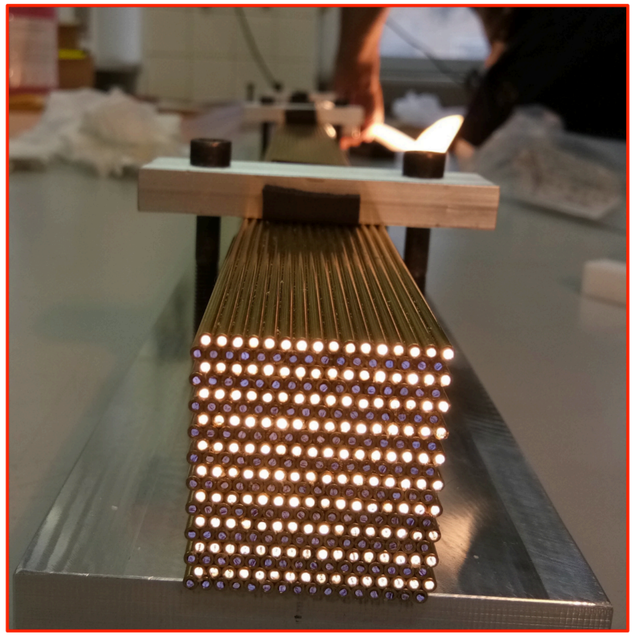
Samples	Rise-Time [ns]	Width [ns]	Time Resolution [ps]
EJ-232	2	9	123
EJ-204	2.5	11	211
2N	2	12	81
2T	3	18	97
1N	3	17	102
2B	2.5	14	110

These scintillators can be:
- **enriched** with **hi-Z** elements (first test with Er and Bi) to better contain high energy X-rays;
- incorporated in **3D printed** resin without losing their properties;

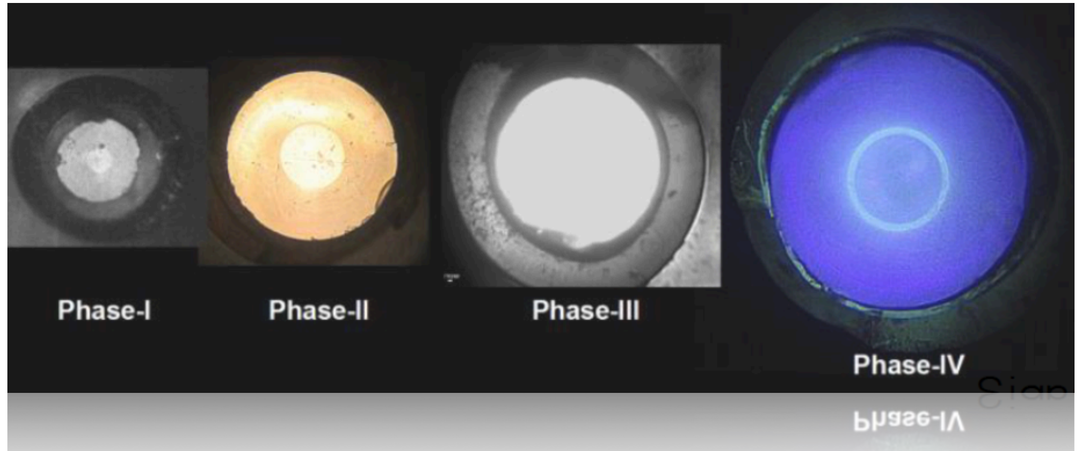
Scintillating Materials: Dual Emission for dual readout



Scintillation fibers



Cherenkov fibers



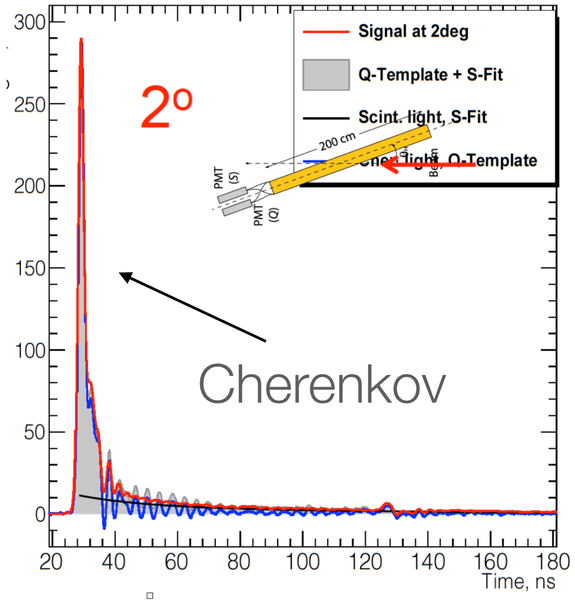
The Cherenkov (SiO_2) and scintillation (SiO_2:Ce3+) light **coexist** in a **single fiber** and can be "tuned."

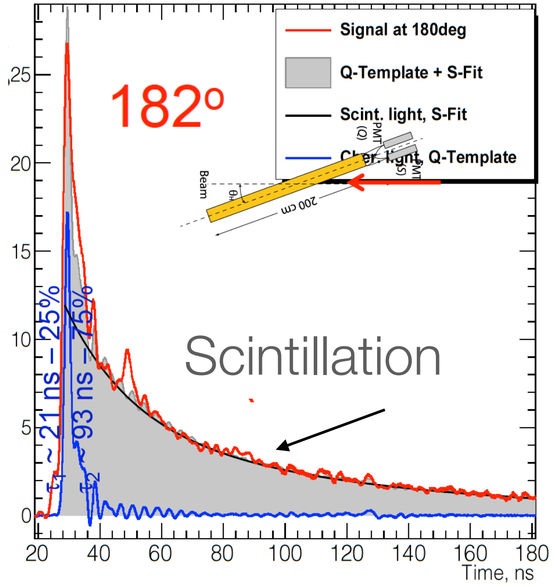
Different fibers for different signals for "spontaneously" **compensated** hadronic calorimeter

$$E = \frac{S - \chi C}{1 - \chi}$$

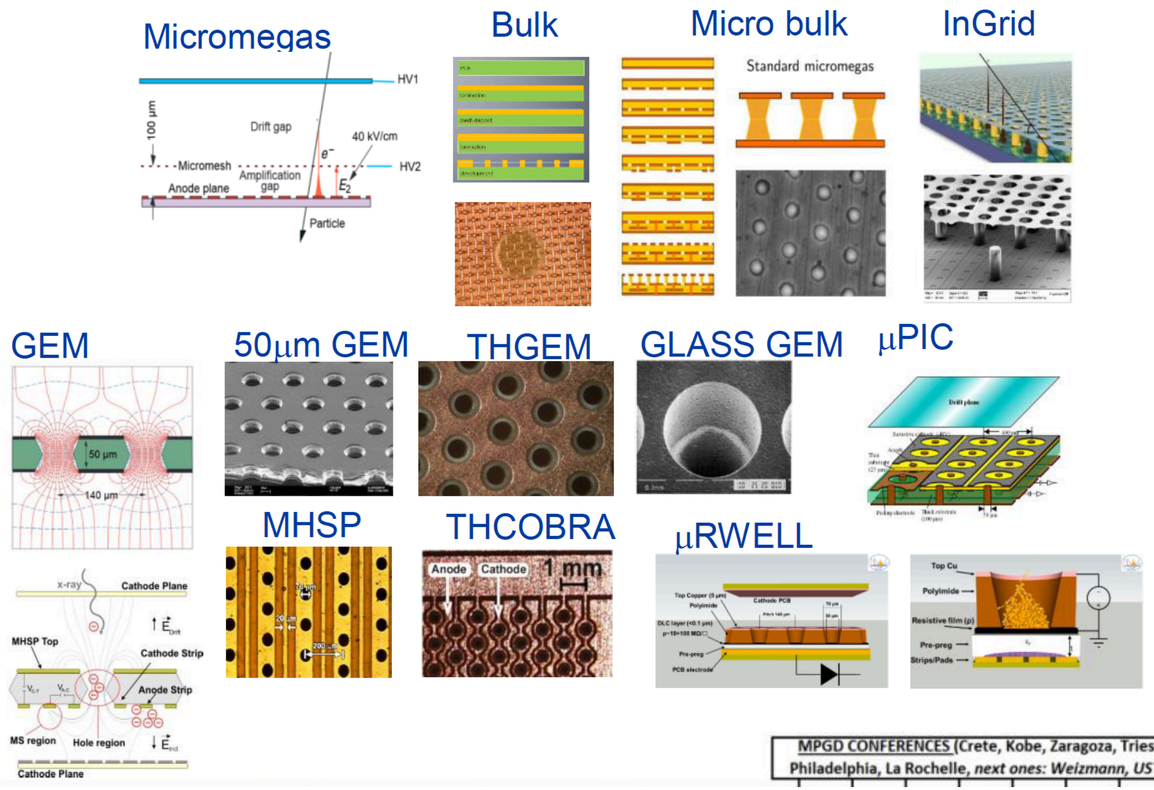
With a single "mixing" parameter

$$\chi = \frac{1 - (h/e)_S}{1 - (h/e)_C} = \frac{E - S}{E - C}$$

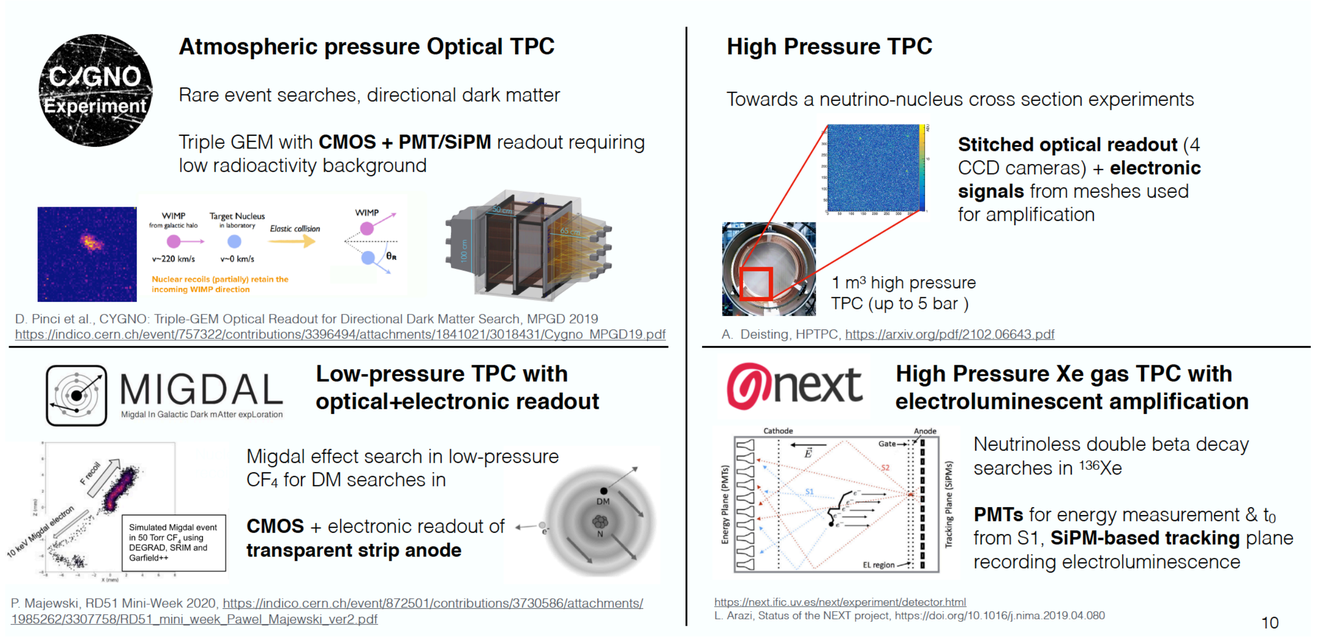




Micro Pattern Gaseous Detectors

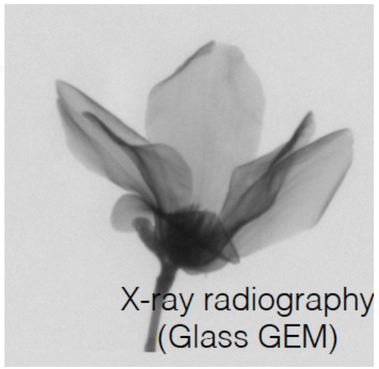


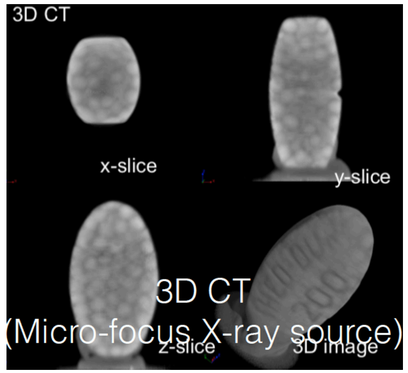
New readout approach: **optical**

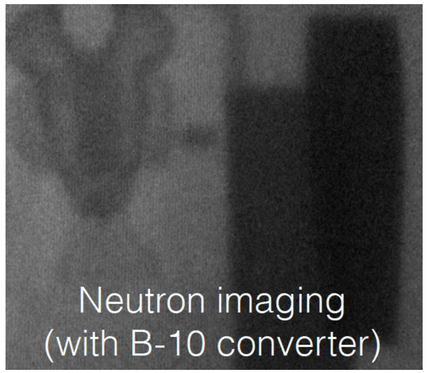


In the last 30 years, large number of different **structures** and **material** studied;

Roma1 is an active component of **RD51 collaboration**;

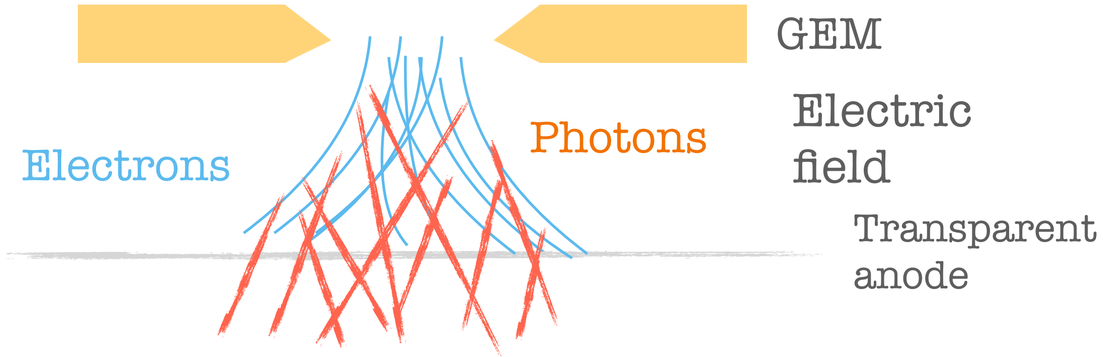


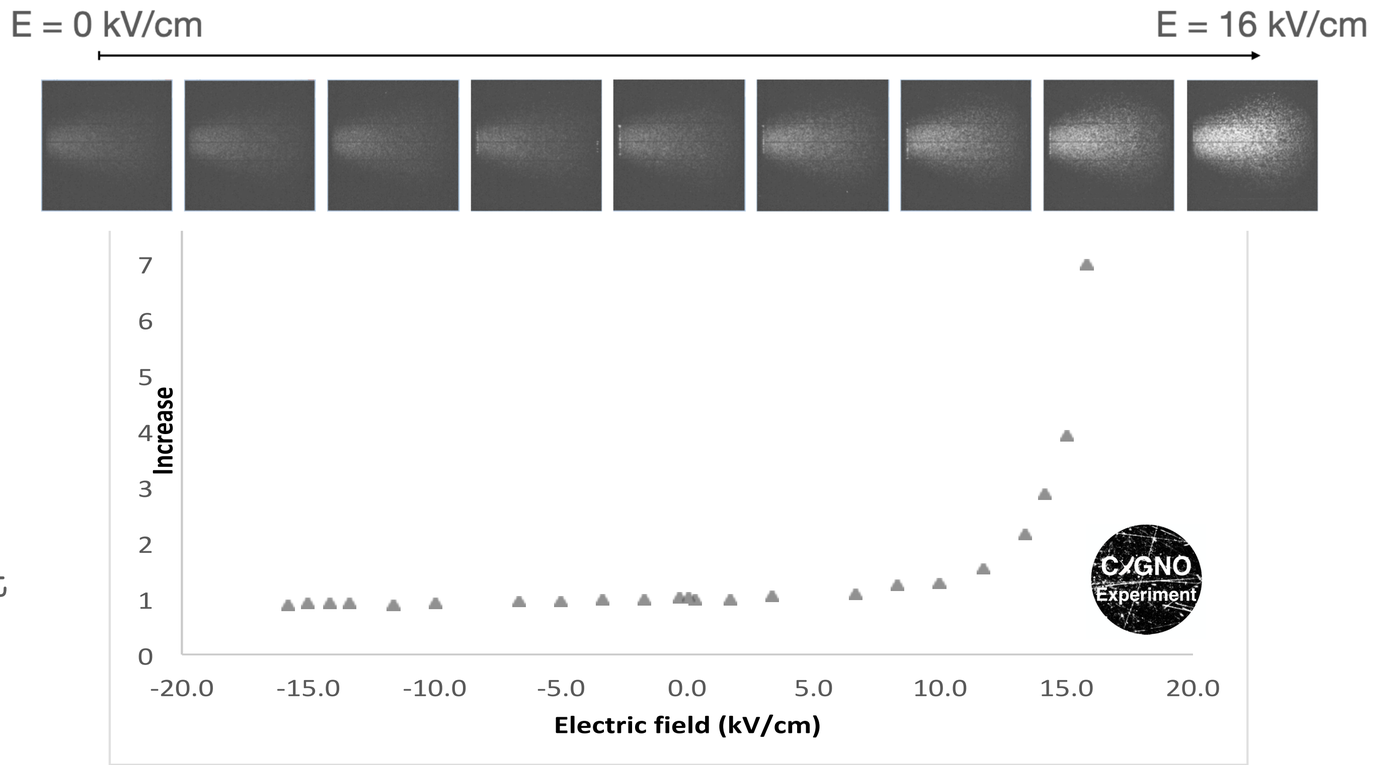




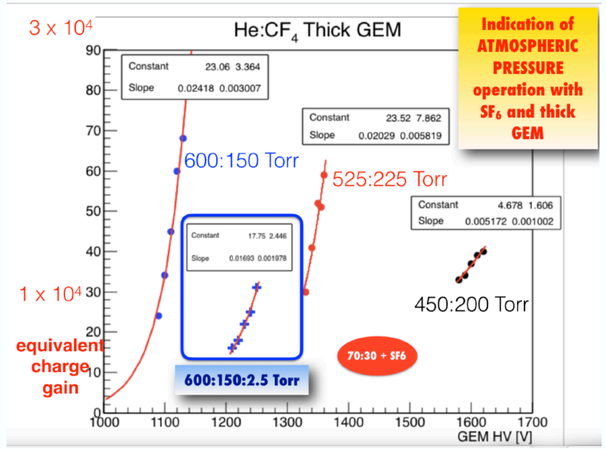
MPGD: Optical readout

Increase the **light** signal by **accelerating** electrons in gas after the multiplication



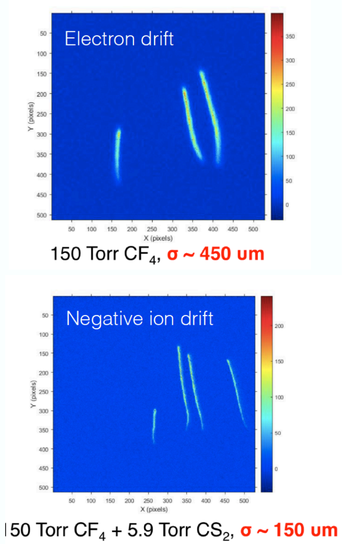


Gain demonstrated in atmospheric pressure He/CF4/SF6



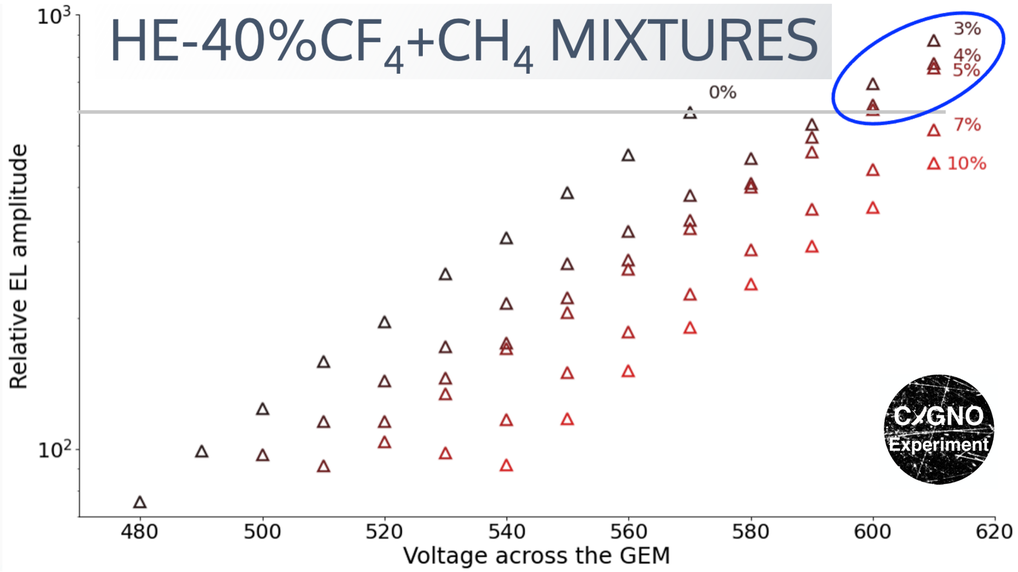
E. Baracchini et al., CYGNO INITIUM, ERC No 818744

NI Optical TPC



D. Loomba, UNM

Addition of **CH_4** increases optical signal **strength** and provides very **light targets** for low mass DM searches



MPGD: Optical readout

QImaging Retiga R6, Thorlabs 8 MP Scientific CCD Cameras

CCD cameras

- **Moderate QE, higher read noise**
- **Low rate (≈tens Hz)**

Exemplary specifications

- 6 MP sensor (2688 x 2200)
- 4.54x4.54μm² pixels size
- 5.7 e- read noise

Hamamatsu ORCA-Fusion, Andor Zyla

sCMOS cameras

- **Low read noise**
- **≈100 Hz frame rate**

Exemplary specifications

- 5.3 MP sensor (2304 x 2304)
- 6.5x6.5μm² pixels size
- 0.7 e- read noise

Hamamatsu ImageEM X2, ams technologies iXon

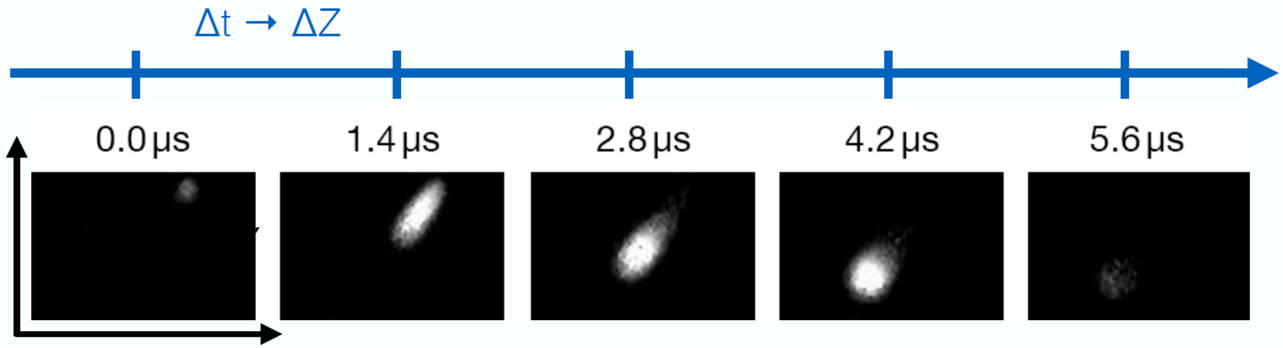
EMCCD cameras

- **Limited resolution**
- **Internal gain, very high sensitivity**

Exemplary specifications

- 1 MP sensor (1024x1024)
- 16x16μm² pixels size
- <1 e- read noise

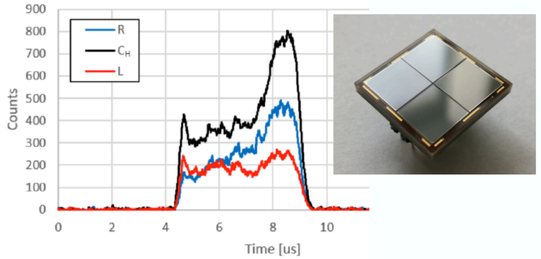
Sequence of images displaying alpha track segments in gaseous TPC recorded at 700 kHz.



Phantom v2512

- 1 megapixel **CMOS** sensor
- **25 kfps** at 1280 x 800
- **1 Mfps** at 128x32
- Higher read noise

Linearly Graded Silicon Photomultipliers (LG-SiPMs)



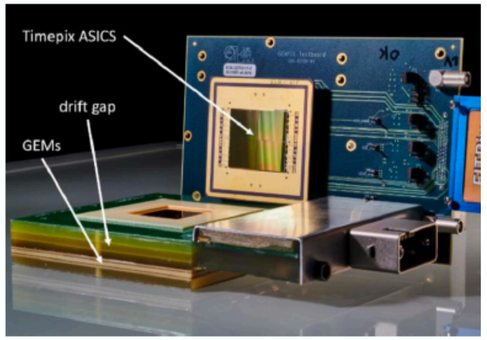
A. Gola et al 2020 JINST 15 P12017
https://doi.org/10.1088/1748-0221/15/12/P12017

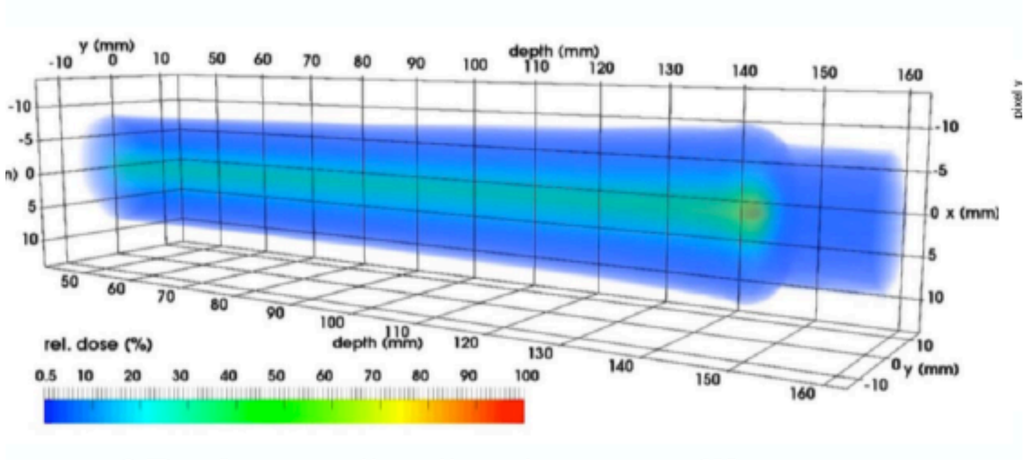
- Current split in four outputs to calculate x and y coordinates from current signals
- Position resolution down to order of size of microcells (30μm)
- Fast response time of tens of ns

MPGD: GEMPix

GEM + Timepix ASIC

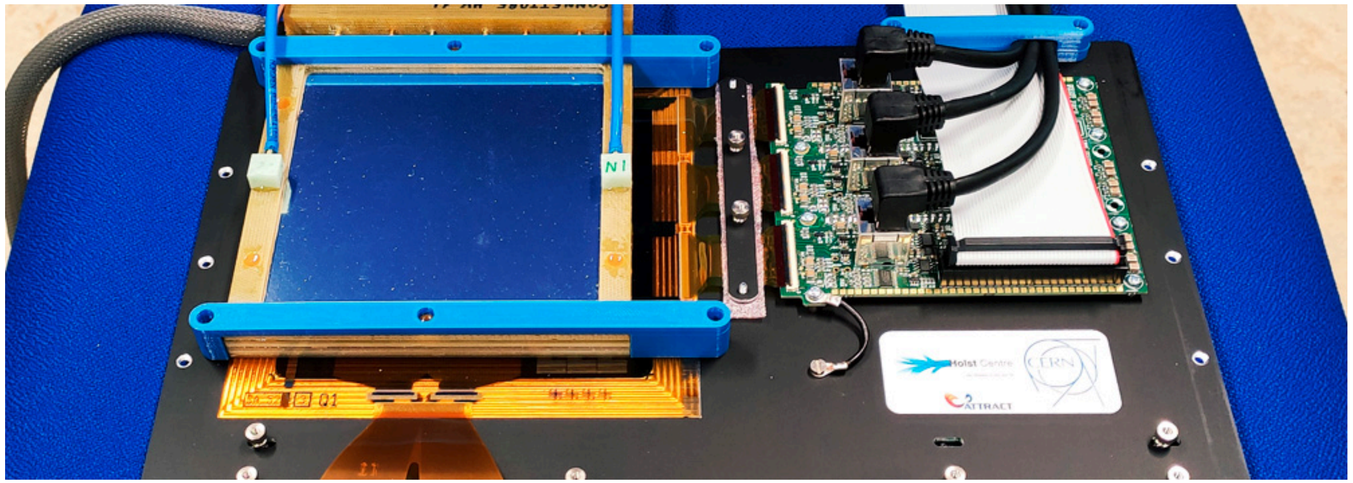
- Four naked Timepix read out with FPGA-based FITPix
- **Dose distribution imaging**, beam profile measurements for **hadron therapy** and micro dosimetry are potential applications
- Limited in area (2.8 × 2.8 cm) by Timepix ASICs -> tiling with Timepix4 feasible

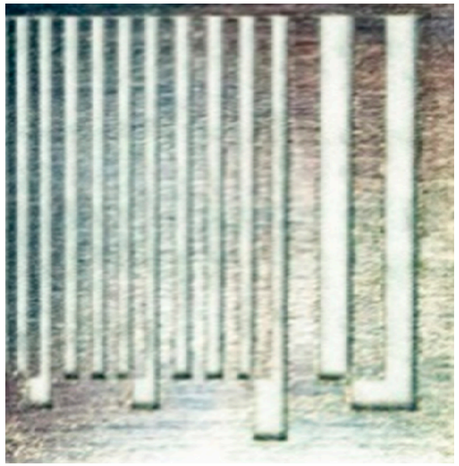


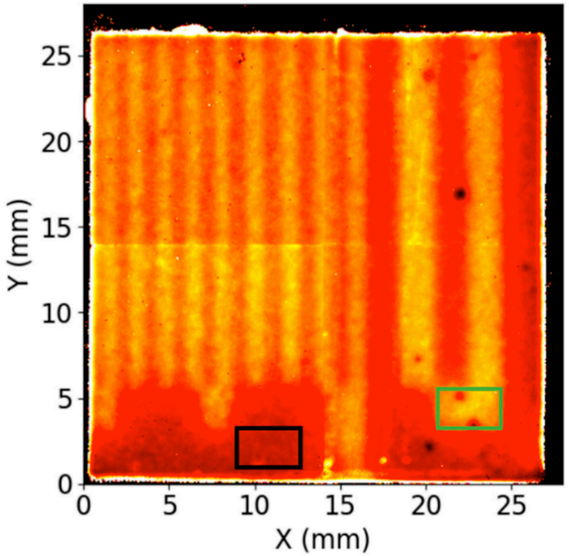


3D dose distribution **profile**

LaGEMPix: **optical photo detectors** (Organic Photo-Diodes) on top of TFT sensitive to scintillation light with 120 μm² pixels

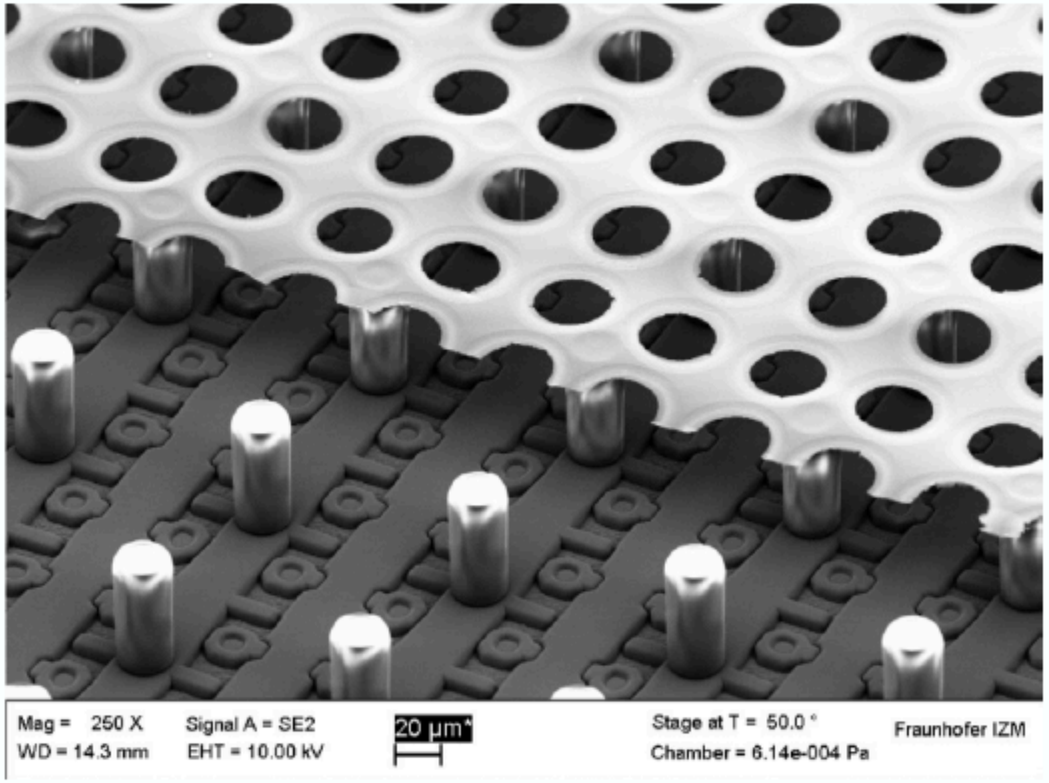






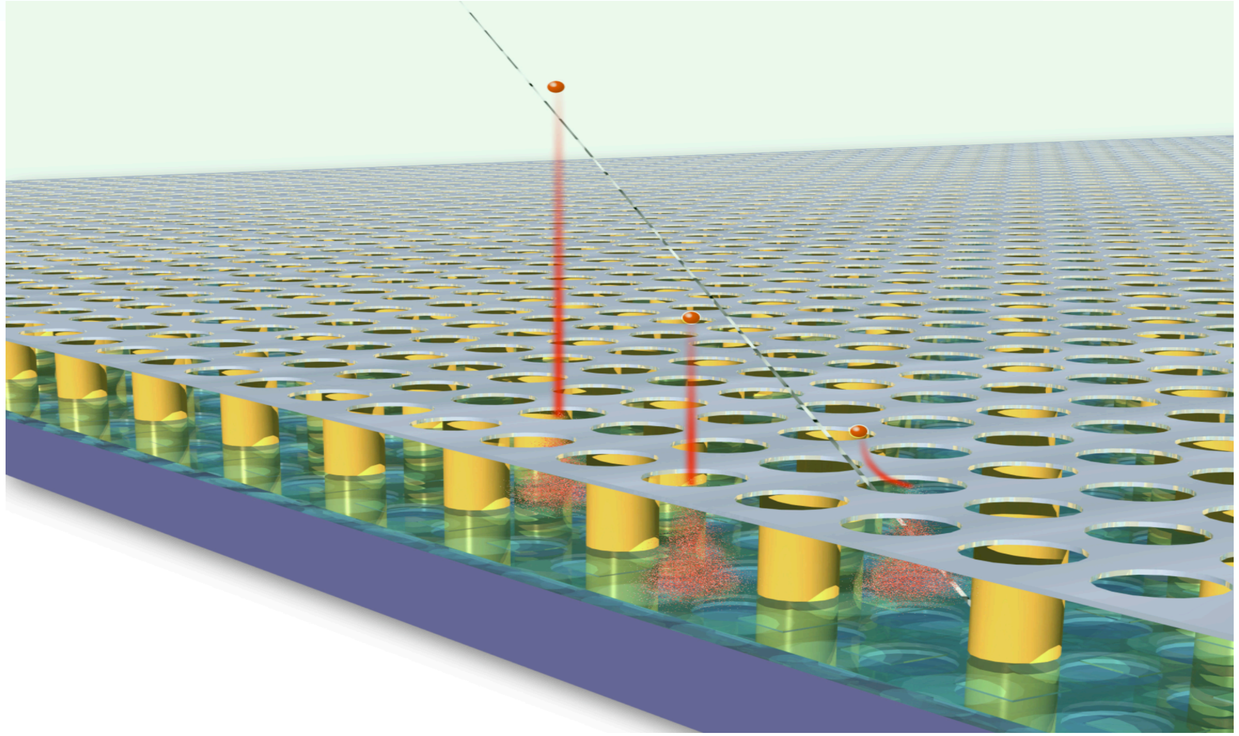
35 keV X-rays mask tomography

MPGD: GridPix



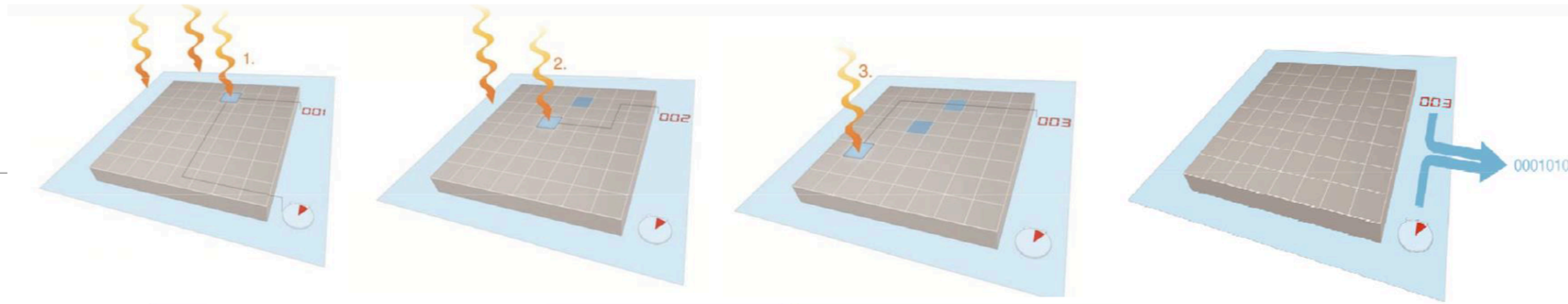
Micromegas on Timepix ASIC

- Bump-bond pads used for charge collection
- CMOS-ASIC designed by the Medipix collaboration
- GridPix based on Timepix 3:
  - 256 × 256 pixels with 55 × 55 μm^2 per pixel
  - Charge (ToT) and time (ToA) information with 1.56ns time resolution

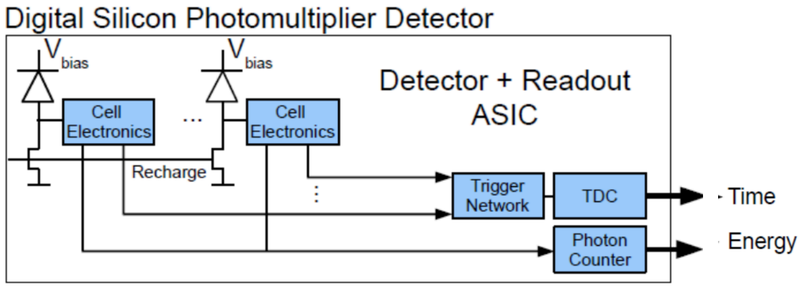


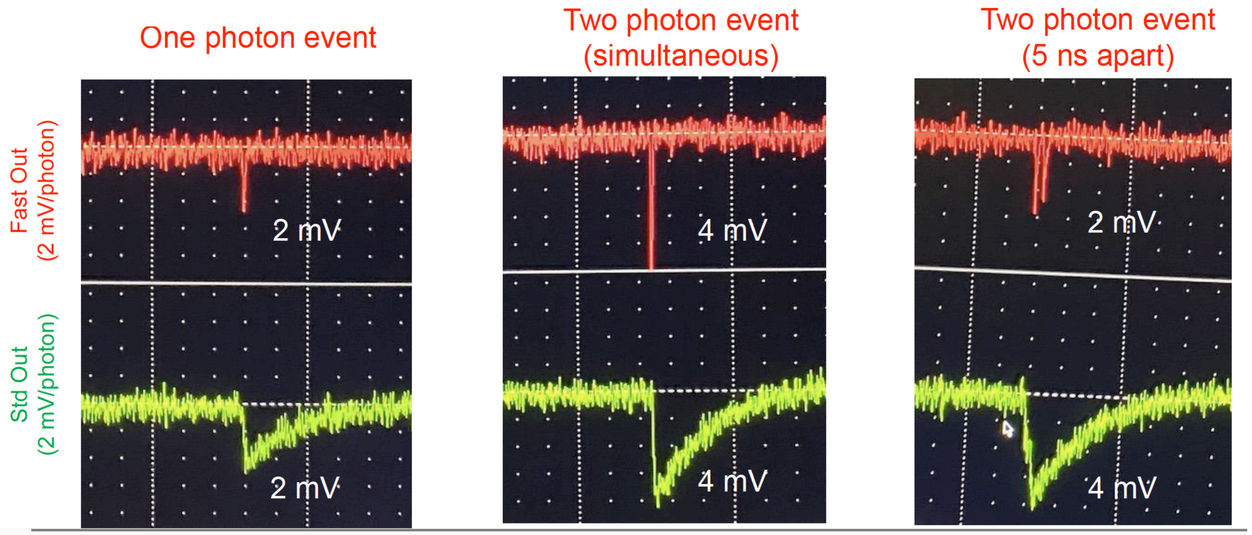
Francesco Renga is studying this device to **readout** a TCP for a possible application to the study of the **electric dipole moment** of the **muon**

Digital SiPM and readout



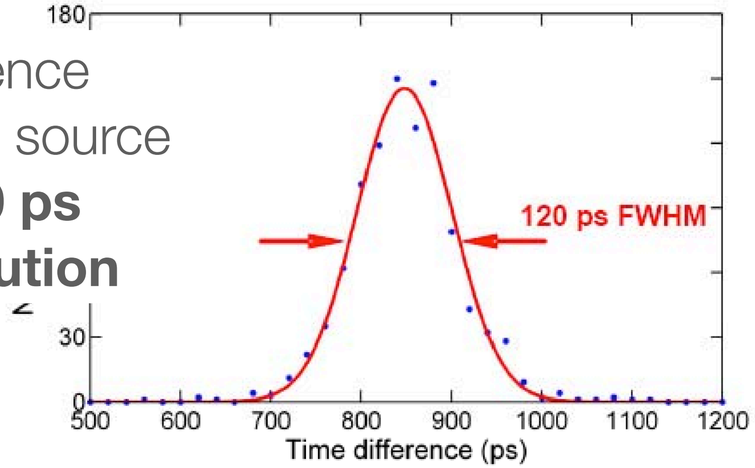
Each **SPAD** is connected to its own **readout** chain up to discrimination: integrated **photon counting mode**



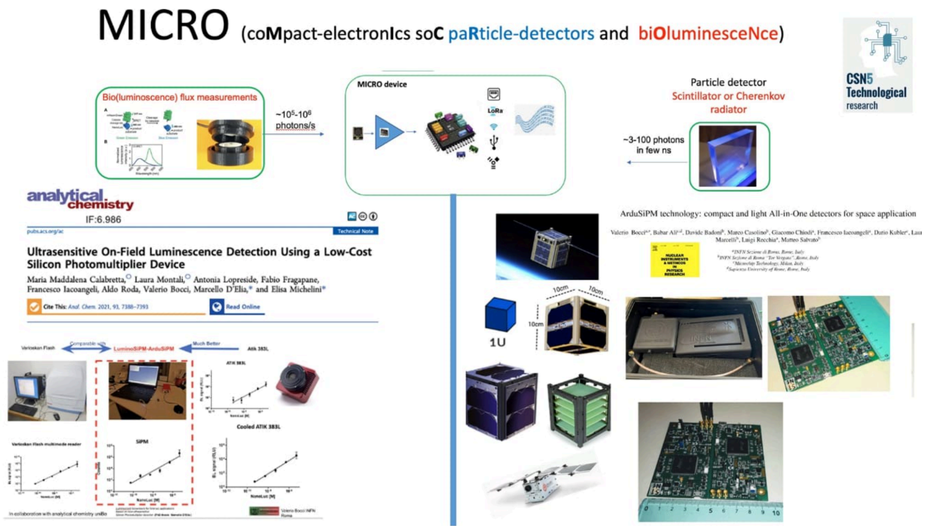


Noisy cells can individually be **switched off**

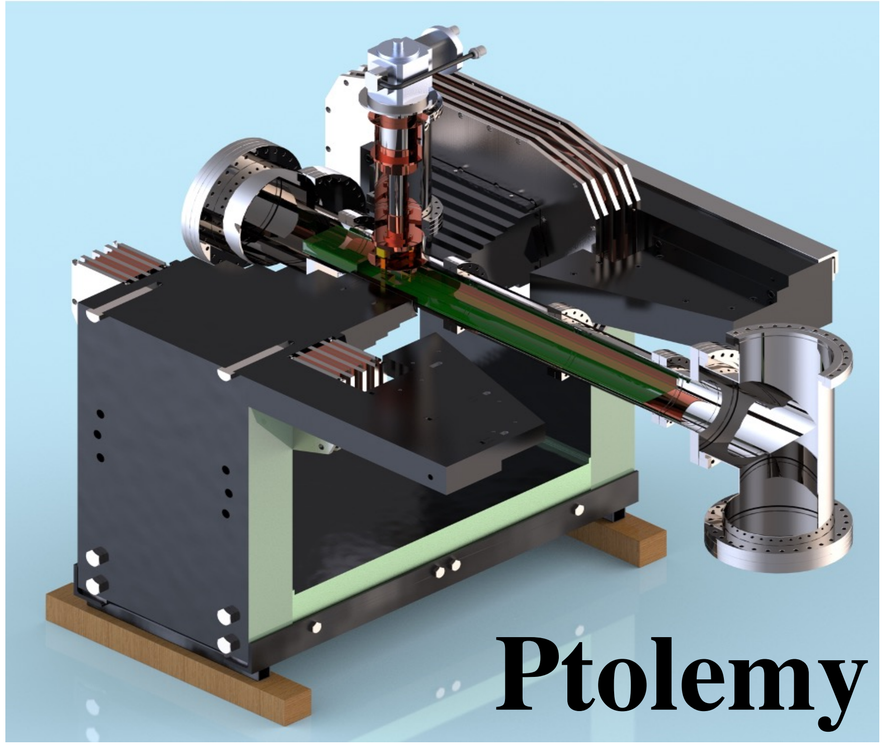
Time difference with a ^{22}**Na** source shows a **50 ps time resolution**

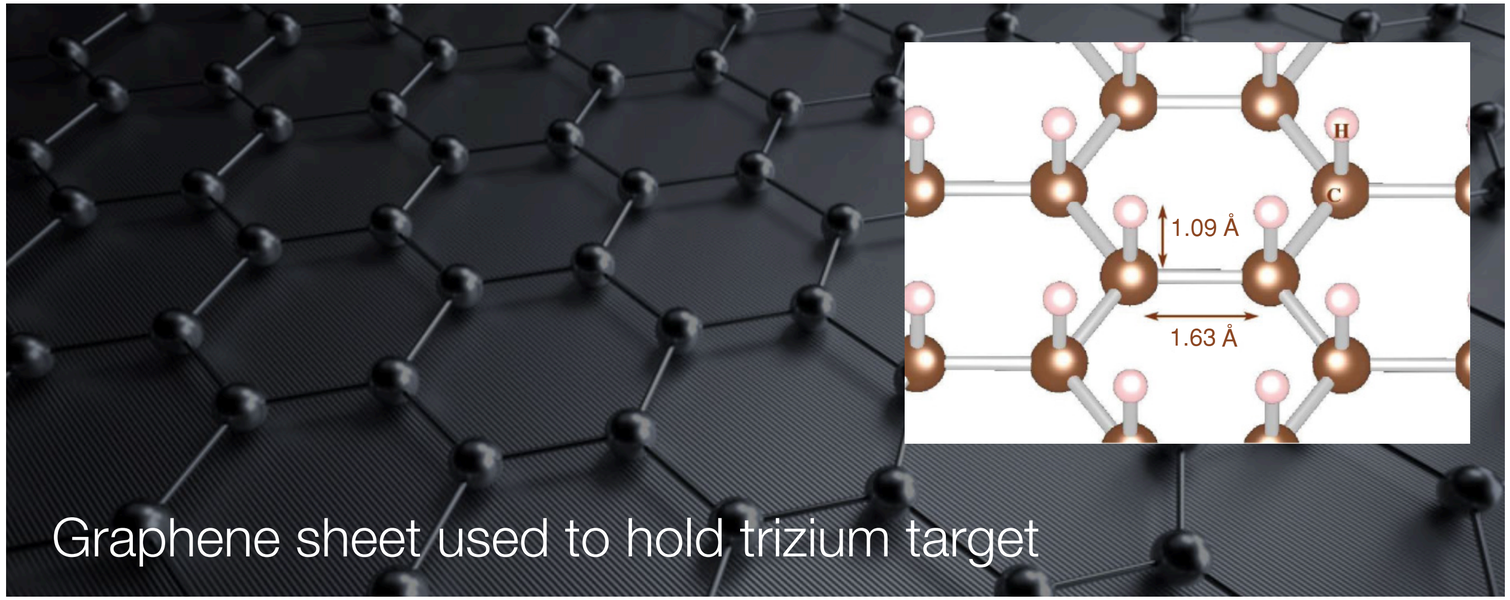


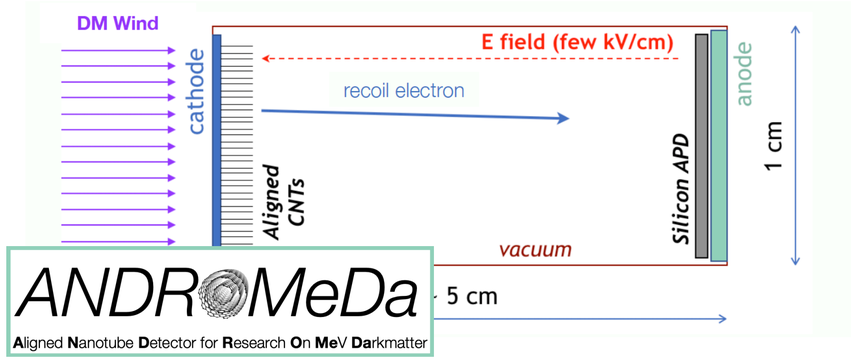
SiPM readout with **industrial** chips for **space** or **bio/chemio-luminescence** applications

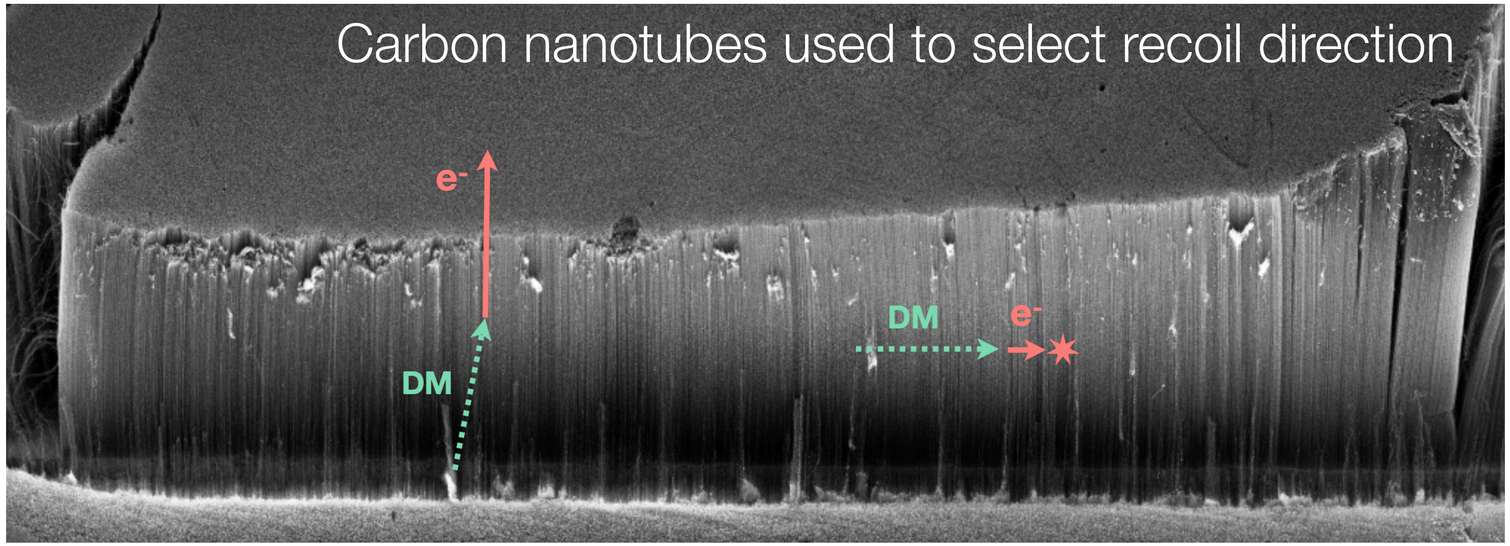


Other Micro Patterns: Carbon nano-structures





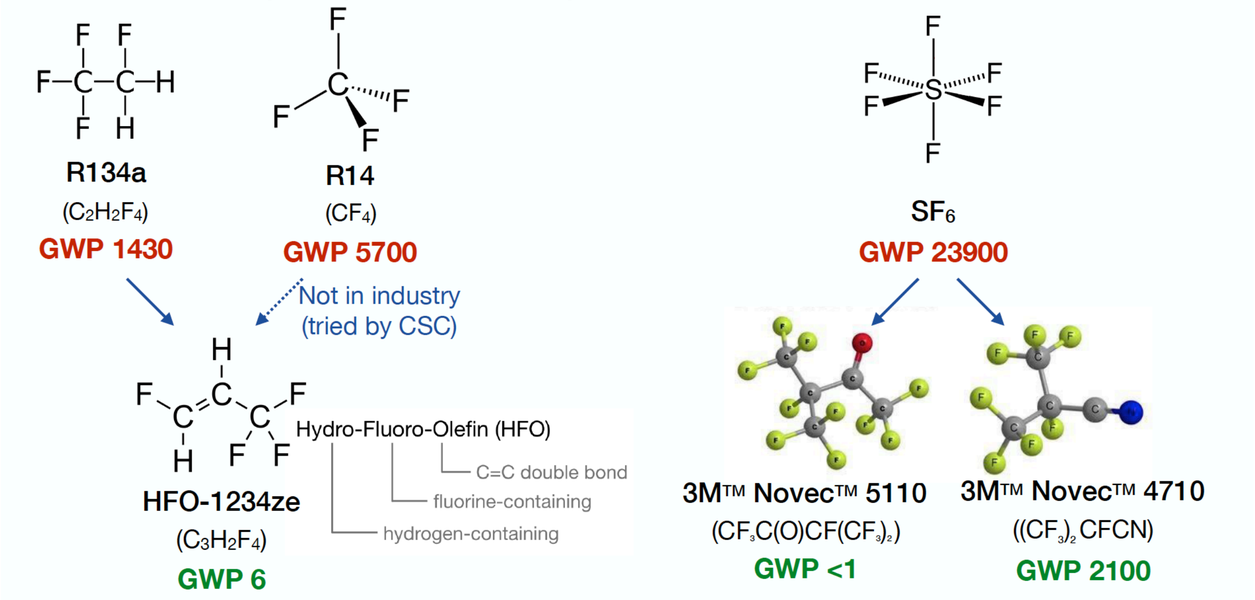


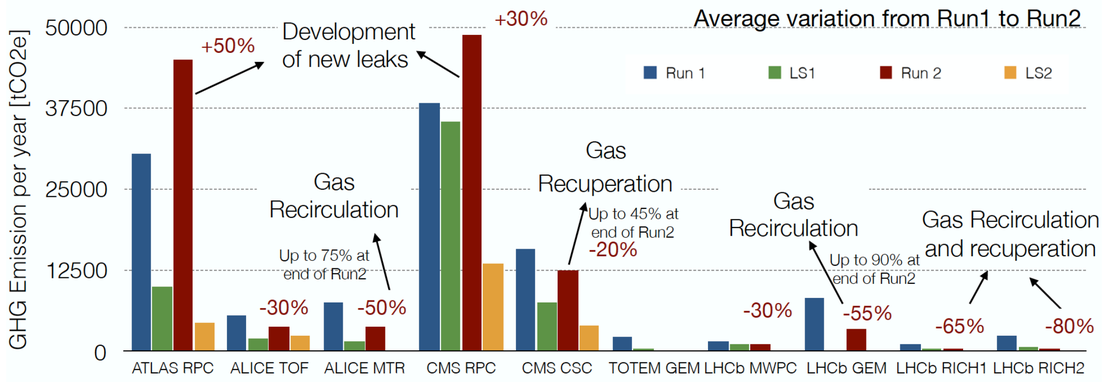


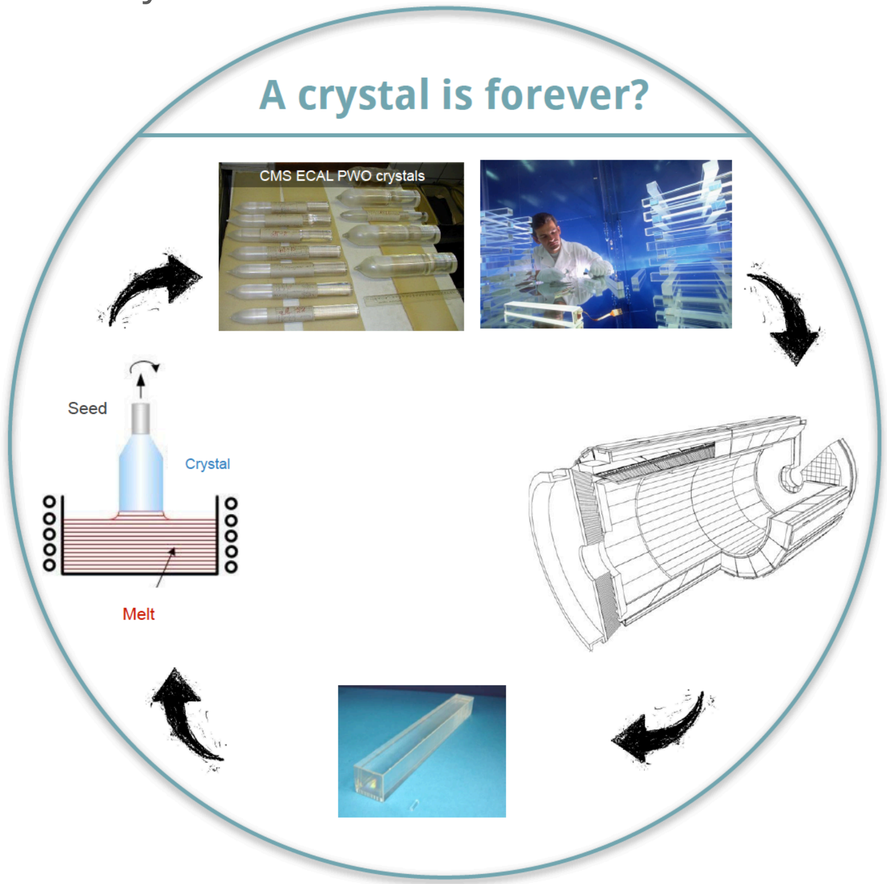
Reduce, re-use, re-cycle

New **eco-friendly** liquids/gases have been developed for industry

Ionisation properties in particle detection not well known







800 BGO crystals recovered from **L3** for **DREAM** and the **PADME** and **FOOT** experiments

Thanks to **recirculation** emission already **reduced** by > **90%**

Conclusion

Wide spectrum of interests and cutting edges activities (I'm sure I forgot big part of them, sorry);

Crucial is the **collaboration** with non-particle physicists: **solid matter**, **chemistry**

To **share** competences and knowledges, we should find:

Time

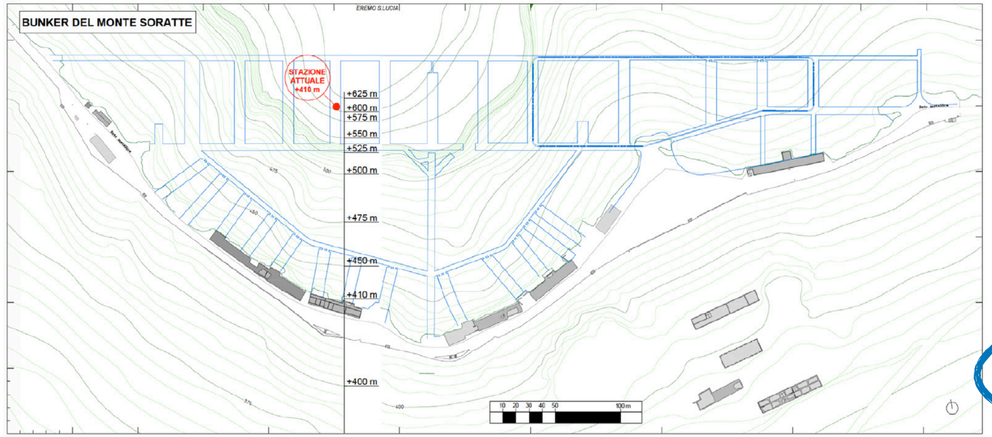
Foresee thematic workshops on experimental and **technological challenges** (low energy measurements, low radioactive detectors, high rate environment);

Space

Some of these activities took place at Segre Laboratories;

We have the opportunity to transform it in a **functional lab** (not a storage place), **with services** (gas, grounding, network) with **room assigned on demand to active groups**.

Other Spaces: Soratte Bunker



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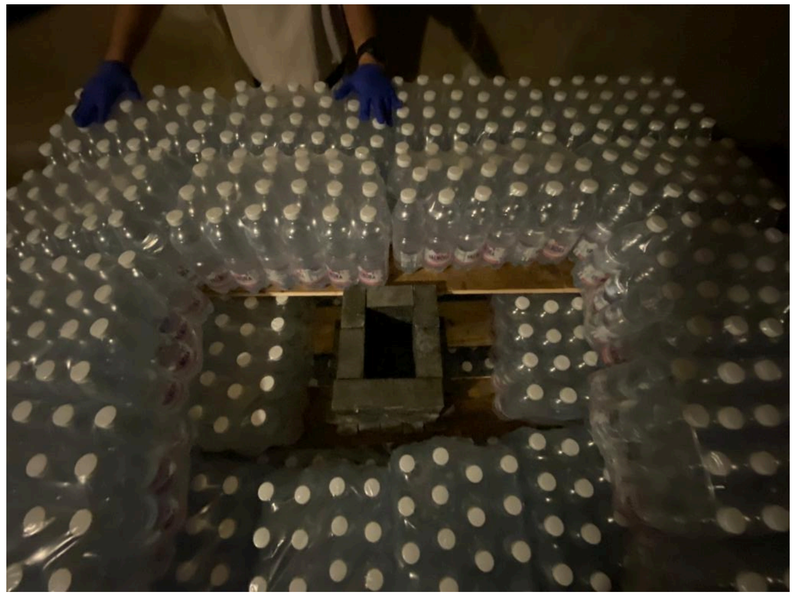
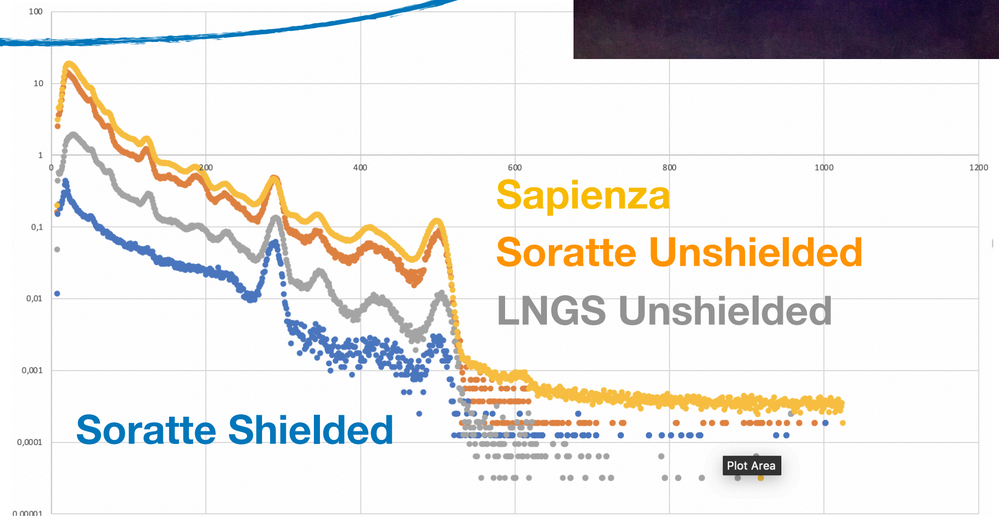
Measurement of the muon flux in the bunker of Monte Soratte with the CRC detector

A. Candela [a], A. Cocco [a], N. D'Ambrosio [a], M. De Deo [a], A. De Iulis [c], M. D'Incecco [a], P. Garcia Abia [d], C. Gustavino [b,*], G. Gustavino [a], M. Messina [a], G. Paolucci [c], S. Parlati [a], N. Rossi [a]

flux. The total averaged muons flux is $\Phi_\mu = 0.3\ \mathrm{m}^{-2}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}$, more than 2 orders of magnitude lower than the typical flux measured on the surface [6,7].





10^1-10^2 less radioactivity

Lot of available room, interesting for R&D